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Original article

Prevalence of malnutrition comparing the GLIM criteria, ESPEN definition and MST malnutrition risk in geriatric rehabilitation patients: RESORT

Angela B. Clark [a], Esmee M. Reijnierse [a], Wen Kwang Lim [a], Andrea B. Maier [a, b, *]

[a] Department of Medicine and Aged Care, @AgeMelbourne, The Royal Melbourne Hospital, The University of Melbourne, 300 Grattan Street, Parkville, 3050, Victoria, Australia
[b] Department of Human Movement Sciences, @AgeAmsterdam, Vrije Universiteit Amsterdam, Amsterdam Movement Sciences, Van der Boechorststraat 7, 1081 BT, Amsterdam, the Netherlands

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SUMMARY

Background & aims: The Global Leadership Initiative on Malnutrition (GLIM) has developed new criteria for the diagnosis of malnutrition. This study aimed 1) to determine and compare malnutrition prevalence and risk using the GLIM criteria, European Society for Clinical Nutrition and Metabolism (ESPEN) definition of malnutrition and the Malnutrition Screening Tool (MST) in patients admitted to subacute geriatric rehabilitation wards, 2) to explore the agreement of malnutrition prevalence determined by each definition, and 3) to determine the accuracy of the MST against the GLIM criteria and ESPEN definition as references.

Methods: Geriatric rehabilitation patients (n = 444) from the observational, longitudinal REStORing health of acutely unwell adulTs (RESORT) cohort in Melbourne, Australia were included. The GLIM criteria, ESPEN definition and MST were applied. Accuracy was determined by the sensitivity, specificity and Area Under the Curve (AUC).

Results: According to the GLIM criteria, the overall prevalence of malnutrition was 52.0%. The ESPEN definition diagnosed 12.6% of patients as malnourished and the MST identified 44.4% of patients at risk for malnutrition. Agreement was low; 7% of patients were malnourished and at risk for malnutrition according to all three definitions. The accuracy of the MST compared to the GLIM criteria was fair (sensitivity 56.7%, specificity 69.0%) and sufficient (AUC 0.63); MST compared to the ESPEN definition was fair (sensitivity 60.7%, specificity 58.0%) and poor (AUC 0.59).

Conclusions: According to the GLIM criteria, half of geriatric rehabilitation patients were malnourished, whereas the prevalence was much lower applying the ESPEN definition. This highlights the need for further studies to determine diagnostic accuracy of the GLIM criteria compared to pre-existing validated tools.

1. Introduction

The prevalence of malnutrition in geriatric rehabilitation populations ranges from 14 to 17% in Asia [1,2], 29–50% in Europe and America [3,4], and 6–53% in Australia [5–8]. Malnutrition in older populations is linked to increased falls risk, decreased quality of life and higher morbidity and mortality [9–12]. Malnourished older adults within residential care, inpatient and outpatient settings show lower physical performance [13], muscle mass, muscle strength [14,15], cognitive functioning and higher risk for depression [16] compared to individuals not malnourished [17,18]. Identification of malnutrition is critical to initiate timely treatment,

Abbreviations: ADL, Activities of daily living; BMI, Body mass index; CGA, Comprehensive Geriatric Assessment; CIRS, Cumulative Illness Rating Scale; ESPEN, European Society for Clinical Nutrition and Metabolism; GIT, Gastro-intestinal tract; GLIM, Global Leadership Initiative on Malnutrition; HADS, Hospital Anxiety and Depression Scale; HGS, Handgrip Strength; IADL, Instrumental Activities of Daily Living; MMSE, Mini-Mental State Examination; MST, Malnutrition Screening Tool; RESORT, REStORing health of acutely unwell adulTs; SMI, Skeletal muscle index; SPPB, Short Physical Performance Battery.

* Corresponding author. Department of Medicine and Aged Care, @Age, The University of Melbourne, The Royal Melbourne Hospital, City Campus, Level 6 North, 300 Grattan Street, Parkville, Victoria, 3050, Australia. fax: +61 3 9342 7866.
E-mail address: andrea.maier@unimelb.edu.au (A.B. Maier).

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however, global consensus for diagnosing malnutrition is still elusive.

Malnutrition screening tools and assessments are developed and validated for different population groups based on different parameters such as anthropometry, appetite, poor oral intake or clinical measures [19–21]. The 2015 consensus statement by the European Society for Clinical Nutrition and Metabolism (ESPEN) developed a global definition for malnutrition offering two alternative diagnostic criteria related to low body mass index (BMI), unintentional weight loss and low fat-free mass index (FFMI) [22]. However, ESPEN's definition omitted etiologic factors of malnutrition and therefore more comprehensive diagnostic criteria were recently developed through ESPEN and the Global Leadership Initiative on Malnutrition (GLIM) [23]. GLIM's etiologic criteria include inflammation, disease burden and reduced food intake or assimilation due to gastrointestinal disorders and symptoms [23]. To diagnose malnutrition according to the GLIM criteria, at least one phenotypic criterion (i.e. low BMI, weight loss and low FFMI) and one etiologic criterion are required based on existing validated reference values. The severity of malnutrition diagnosis is based on pre-established cut-offs for the etiologic parameters.

There are currently no studies showing malnutrition prevalence in geriatric rehabilitation patients using the new GLIM criteria, thus the present study will 1) determine and compare malnutrition prevalence and risk using the GLIM criteria, ESPEN definition and the Malnutrition Screening Tool (MST); 2) explore the agreement of malnutrition prevalence determined by each definition; and 3) determine the accuracy of the MST against the GLIM criteria and ESPEN definition.

2. Materials and methods

2.1. Study design

REStORing health of acutely unwell adulTs (RESORT) is an ongoing longitudinal, observational inception cohort assessing the physical, cognitive and physiological status by using a Comprehensive Geriatric Assessment (CGA) in subacute geriatric rehabilitation patients. The study commenced 16 October 2017, with 693 patients prospectively recruited in wave 1 from geriatric rehabilitation wards at the Royal Melbourne Hospital (Melbourne, Victoria, Australia) until discharge by 31 August 2018. The study was approved by Melbourne Health Human Research Ethics Committee (no. HREC/17/MH/103) and follows national and international ethical guidelines according to the Helsinki Declaration [24], the National Statement on Ethical Conduct in Human Research (2007) [25] and the Guidelines for Good Clinical Research Practice [26]. Written informed consent was obtained for each patient by the patient themselves or a nominated proxy. Excluded patients (n = 152, 15.3%) were those receiving palliative care, patients transferred to acute care prior to consenting to the study and patients incapable of providing informed consent (e.g. patients with delirium or severe dementia) without a nominated proxy. Patients were assessed within 48 h of admission to the geriatric rehabilitation wards by physicians, nurses, physiotherapists, occupational therapists and dietitians.

2.2. Patient characteristics

Characteristics of patients included age and sex. Cognitive status was assessed by the Mini-Mental State Examination (MMSE) with a score range of 0–30 points [27]. Patients completed a patient admission questionnaire containing the Hospital Anxiety and Depression Scale (HADS) or were assisted to complete the questionnaire by their next of kin, a carer or researcher. A HADS score $\geq$11 points out of 21 signified clinically significant symptoms of anxiety and depression [28]. Anthropometric and muscle measures were taken by trained nurses. Standing height without footwear was measured when the patient could stand; knee height was measured when the patients were unable to stand. Knee height was taken using a sliding calliper with knee and ankle joints positioned at 90° before calculating estimated height with the LASA equation for Caucasians [29]. Weight (measured to nearest 0.1 kg) was taken on a calibrated standing scale, weighing chair or hoist without shoes or heavy clothing. BMI was calculated as body weight divided by height squared (kg/m^2).

Body composition was determined using direct-segmental multi-frequency bioelectrical impedance analysis (DSM-BIA, InBody S10, Biospace Co., Ltd, Seoul, South Korea). BIA analysis has been validated for assessing segmental and whole body composition against dual energy X-ray absorptiometry (DEXA) and is portable and accessible for non-ambulatory patients and therefore more practical on hospital wards. BIA measured skeletal muscle mass (SMM) in kilograms and skeletal muscle mass index (SMI) was calculated by dividing SMM (kg) by height squared (m^2) [30]. Cut-offs used for moderate and severe muscle deficit were based on established disability-related SMI thresholds for older adults according to Janssen et al. [31] i.e. moderate: $\leq$6.75 kg/m^2 for females, $\leq$10.75 kg/m^2 for males; severe: $\leq$5.75 kg/m^2 for females, $\leq$8.50 kg/m^2 for males. BIA was not performed on patients with an electronic internal medical device or implant such as a pacemaker, or if electrodes could not be placed due to positioning of plasters or bandages, patients with an amputation or patients under contact isolation.

The physical domain assessments were performed by trained physiotherapists. Handgrip strength was measured with a hand-held dynamometer (JAMAR, Sammons Preston, Inc., Bolingbrook, IL, USA). Patients were instructed to squeeze the dynamometer to their maximum strength ability. Three trials were performed for each hand alternating between the left and right hand side and the maximum value was used and expressed in kilograms [32]. The Short Physical Performance Battery (SPPB) assessment was scored on a scale ranging from 0 to 12 points. The SPPB consists of three tests i.e. standing balance, 4-m walk test and the chair sit-to-stand test with higher scores demonstrating higher levels of physical function [33].

Functional independence status was assessed by occupational therapists using Activities of Daily Living (ADL) and Instrumental Activities of Daily Living (IADL). ADLs were assessed using the Katz index with scores ranging from 0 to 6 [34] and IADLs using the Lawton and Brody scale with scores ranging from 0 to 8 [35], greater scores indicating higher levels of independence for both scales. The use of a walking aid was self-reported.

Disease burden was documented by physicians using the 56-point Cumulative Illness Rating Scale (CIRS) in which higher points indicated higher morbidity [36]. Physicians assessed frailty via the Clinical Frailty Scale (CFS) which uses a 9-point scale from 1 (very fit) to 9 (terminally ill) [37].

2.3. GLIM criteria

The GLIM criteria [23] for phenotypic assessment included: non-volitional weight loss (1 to >15 kg in the past 6 months recorded on the MST) and/or low BMI (<20 kg/m^2 if < 70 years, or <22 kg/m^2 if $\geq$ 70 years) or reduced muscle mass (SMI $\leq$6.75 kg/m^2 and $\leq$10.75 kg/m^2 in females and males respectively) [31]. Moderate (stage 1) and severe malnutrition (stage 2) cut-offs were applied according to the extent of weight loss, BMI cut-offs and deficit in reduced muscle mass shown in Fig. 1.

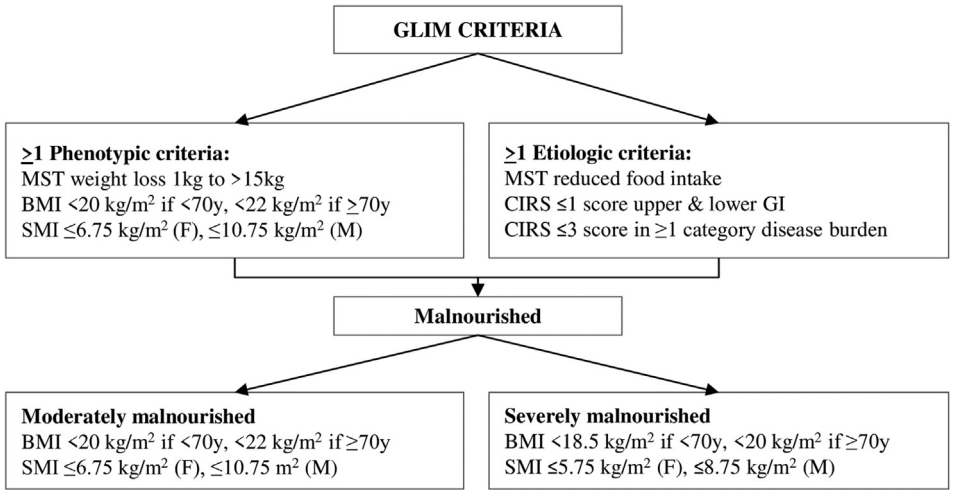

Fig. 1. Flowchart of GLIM Criteria for assessment and diagnosis of malnutrition. GLIM: Global Leadership Initiative on Malnutrition; MST: Malnutrition Screening Tool; BMI: Body mass index; y: years; SMI: Skeletal muscle mass index; F: female; M: male; CIRS: Cumulative Illness Rating Scale; GI: Gastro-intestinal tract.

GLIM's etiologic assessment involved three domains; 1) reduced food intake for >2 weeks, or 2) any chronic gastrointestinal condition adversely impacting food assimilation or absorption and/or 3) disease burden and/or an inflammatory condition (acute disease/injury or chronic disease, or moderate to severe inflammation). Reduced food intake was identified by answering "yes" to the MST question "Have you/the patient been eating poorly because of a decreased appetite?"(38). The CIRS was used to indicate gastrointestinal tract (GIT) symptoms where a patient had ≥1 condition in either lower and/or upper gastrointestinal systems. Moderate to severe inflammatory status and acute or chronic level of disease burden were defined as one or more organ systems with a score ≥3 in one or more CIRS categories, aligning with severe, significant disability or chronic health problems. The cut-off of ≥3 in at least one CIRS category has previously been used to screen geriatric patients at risk of morbidity and mortality [39].

2.4. ESPEN

The ESPEN definition was applied using predetermined cut-offs [22]. Diagnostic criteria entailed: 1) BMI <18.5 kg/m^2 and/or 2) unintentional weight loss (1 to >15 kg weight loss in past 6 months) and either a) low BMI (<20 kg/m^2 if younger than 70 years or <22 kg/m^2 if older than 70 years) or b) FFMI <15 kg/m^2 and <17 kg/m^2 in females and males respectively [31]. FFMI was derived by BIA, dividing fat-free mass (FFM) by height squared.

2.5. MST malnutrition risk

All patients were screened for malnutrition within 48 h of admission by a trained nurse, using the MST [38] which is validated for use amongst hospitalised patients and found to have high accuracy in identifying malnutrition in older patients [40,41]. An MST score of 2 or more classifies patients as at risk of malnutrition while patients scoring 0 to 1 were not at risk of malnutrition.

2.6. Statistical analysis

Patient characteristics were analysed using descriptive statistics. Categorical variables were presented as a numeric value (n) with percentages (%). Continuous variables that were normally distributed were reported as mean with standard deviation (SD) values, and when skewed, median values with interquartile range [IQR] were reported.

Prevalence of malnutrition was determined according to GLIM criteria, ESPEN definition and MST malnutrition risk. A Venn diagram was used to visualise the agreement between each definition. Different phenotypes were created based on the three definitions and characteristics were compared between the eight phenotypes i.e. GLIM, GLIM&ESPEN, GLIM&MST, GLIM&ESPEN&MST, ESPEN, ESPEN&MST, MST and not malnourished according to any of the three definitions. To determine the accuracy of the MST against the GLIM criteria and ESPEN definition, sensitivity and specificity were calculated and the Area Under the Curve (AUC) and kappa coefficient determined. Sensitivity and specificity were classified as poor if <50%, fair if >50% and <80%, good if ≥ 80% [42]. AUC was classified as poor if < 0.60, fair 0.60–0.80, and good >0.80 [42,43]. The kappa coefficient was classified by values > 0.80 to indicate very good agreement; 0.61 to 0.80 good agreement, 0.41–0.60 moderate agreement, 0.21–0.40 fair agreement and <0.20 poor agreement [44].

Data-analyses were performed using the Statistical Package for the Social Sciences (SPSS) (IBM SPSS Advanced Statistics 24.0, Armonk, NY, IBM Corp).

3. Results

3.1. Patient characteristics

Table 1 shows the patient characteristics. The mean age was 82.4 ± 8.01 years and 56.8% were female. Median handgrip strength was 14 kg [IQR: 10–18] for females and 20 kg [IQR: 16–28] for males, and the median SPPB score was 2 [IQR: 0–4]. Seventy-nine percent of patients used a walking aid and the median frailty score was 6 [IQR: 5–7]. More than half the patients (53.8%) had GIT symptoms and the mean CIRS score was 11.3 ± 4.71 points.

3.2. Prevalence of malnutrition and MST malnutrition risk

Table 2 shows the assessment criteria for malnutrition according to GLIM criteria, ESPEN definition, and MST malnutrition risk. The overall prevalence of malnutrition according to GLIM criteria was 52.0%. GLIM criteria diagnosed moderate malnutrition in 36.0% and severe malnutrition in 16.0% of geriatric rehabilitation patients. Twelve percent of patients were diagnosed malnourished by the

Table 1
Patient characteristics at admission (n = 444).

Demographics	Total	Females(n = 252)	Males (n = 192)
Age, years	82.4 (8.01)	81.9 (8.23)	83.1 (7.69)
MMSE, score, median [IQR]	22 [17–26]	23 [19–26]	21 [16–25]
HADS anxiety, score, median [IQR]	5 [2–9]	5 [2–10]	4 [1–9]
HADS depression, score, median [IQR]	6 [2–10]	6 [3–10]	6 [2–11]
BMI, kg/m^2	27.3 (6.28)	27.8 (6.55)	26.6 (6.23)
MST, score, median [IQR]	1 [0–2]	0 [0–1]	0 [0–1]
Muscle measures and Physical Function			
SMI, kg/m^2	8.89 (1.46)	8.45 (1.32)	9.49 (1.43)
HGS (kg), median [IQR]	17.2 (7.39)	14.1 (5.51)	21.8 (7.40)
SPPB, score, median [IQR]	2 [0–4]	2 [0–4]	2 [0–4]
ADL score, median [IQR]	2 [1–3]	2 [1–3]	2 [1–2]
IADL score, median [IQR]	1 [0–1]	1 [0–2]	0 [0–1]
Use walking aid, n (%)	250 (79.4)	146 (81.6)	104 (76.5)
Disease and Frailty			
CIRS, score	11.3 (4.71)	11.0 (4.61)	11.7 (4.82)
GIT symptoms, n (%)	239 (53.8)	141 (56.0)	98 (51.0)
Frailty, score, median [IQR]	6 [5–7]	6 [5–6]	6 [5–7]

Data presented as mean (SD) unless otherwise indicated. SD: standard deviation; IQR: interquartile range; MMSE: Mini-Mental State Examination; HADS: Hospital Anxiety and Depression Scale; BMI: Body Mass Index; MST: Malnutrition Screening Tool; SMI: Skeletal Muscle Index; HGS: Handgrip Strength; SPPB: Short Physical Performance Battery; IADL: Instrumental Activities of Daily Living; ADL: Activities of Daily Living; CIRS: Cumulative Illness Rating Scale; GIT: Gastrointestinal tract.

Table 2
Assessment criteria for malnutrition diagnosis according to GLIM, ESPEN and MST malnutrition risk at admission (N = 444).

Criteria	Cut-off	Prevalence n (%)
GLIM phenotypic criteria		
Weight loss	1 to >15 kg weight loss in past 6 months	91 (20.5)
Low BMI	<20 kg/m^2 if < 70 y or <22 kg/m^2 if ≥ 70 y	88 (19.8)
Low SMI	≤6.75 kg/m^2 (F), ≤10.75 kg/m^2 (M)	171 (39.1)
Weight loss or low BMI or low SMI		255 (57.4)
GLIM etiologic criteria		
Reduced food intake/assimilation	>2 weeks reduced intake and/or ≥1 GIT symptom	284 (64.0)
Disease burden or inflammatory condition	≥3 score in ≥1 CIRS category	321 (72.3)
Reduced food intake or assimilation or inflammation		386 (86.9)
Stage 1/Moderate malnutrition		
Low BMI	<20 kg/m^2 if < 70 y or <22 kg/m^2 if ≥ 70 y	44 (9.90)
Moderate deficit SMI	≤6.75 kg/m^2 (F), ≤10.75 kg/m^2 (M)	122 (27.9)
Weight loss	1 to >15 kg weight loss in past 6 months	91 (20.5)
Low BMI or moderate deficit SMI or weight loss		178 (40.1)
GLIM prevalence of moderate malnutrition		160 (36.0)
Stage 2/Severe malnutrition		
Low BMI	<18.5 kg/m^2 if < 70 y or <20 kg/m^2 if ≥ 70 y	44 (9.90)
Severe deficit SMI	≤5.75 kg/m^2 (F), ≤8.50 kg/m^2 (M)	49 (11.2)
Weight loss	1 to >15 kg weight loss in past 6 months	91 (20.5)
Low BMI or severe deficit SMI or weight loss		77 (17.3)
GLIM prevalence of severe malnutrition		71 (16.0)
Overall GLIM prevalence		231 (52.0)
ESPEN criteria		
Option 1: Low BMI	<18.5 kg/m^2	23 (5.20)
Option 2: Weight loss	1 to >15 kg weight loss in past 6 months	91 (20.5)
Low BMI	<20 kg/m^2 if < 70 y or <22 kg/m^2 if ≥ 70 y	88 (19.8)
Low FFMI	<15 kg/m^2 (F), <17 kg/m^2 (M)	134 (30.7)
ESPEN prevalence of malnutrition		56 (12.6)
MST malnutrition risk		
Weight loss	1 to >15 kg weight loss in past 6 months	91 (20.5)
Reduced food intake	Yes/No	108 (24.3)
MST prevalence of malnutrition risk		197 (44.4)

BMI: Body mass index; FFMI: Fat-Free Mass Index; MST: Malnutrition Screening Tool; SMI: Skeletal Muscle Index; CIRS: Cumulative Illness Rating Scale; GIT: Gastrointestinal tract.

ESPEN definition and MST malnutrition risk showed 44.4% of patients were at risk.

Figure 2 represents the agreement of malnutrition prevalence and malnutrition risk according to each definition. Thirty-two (7.2%) patients were screened as at risk of malnutrition and diagnosed malnourished by GLIM, ESPEN and MST definitions. Ninety-one percent (n = 51) of patients being malnourished according to the ESPEN definition, were also diagnosed by the GLIM criteria. Sixty-four patients (32.5%) identified by MST malnutrition risk were not diagnosed with malnutrition by GLIM or ESPEN, and eighty-one patients (35.1%) identified by GLIM did not screen positive for MST malnutrition risk. When applying the GLIM criteria and ESPEN definition in only patients that screened positive for MST malnutrition risk, the prevalence was 29.5% (n = 131) using GLIM and 7.7% (n = 34) using ESPEN.

Table 3 shows the characteristics of patients identified as malnourished and not malnourished according to GLIM, ESPEN and MST phenotypic groupings. Patients diagnosed by

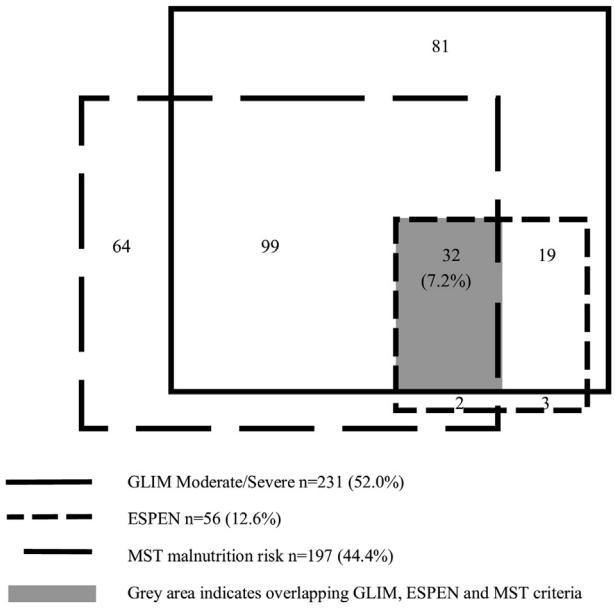

Fig. 2. Number of patients identified as having malnutrition diagnosis or risk of malnutrition according to GLIM, ESPEN and MST overlapping criteria. Of 444 patients assessed, 144 were not malnourished. GLIM: Global Leadership Initiative on Malnutrition; ESPEN: European Society for Clinical Nutrition and Metabolism; MST: Malnutrition Screening Tool.

GLIM&ESPEN&MST malnutrition risk had the lowest median handgrip strength values for both females and males compared to the other phenotypic groups. The proportion of malnourished males within the GLIM group and combined GLIM&ESPEN group were 68% and 74% respectively. A high percentage of females were found in the MST group and not malnourished groups (86% and 76% respectively).

Table 4 shows the accuracy of the MST malnutrition risk tool in reference to GLIM and ESPEN diagnostic tools. Sensitivity and specificity of the MST tool compared with GLIM was fair (56.7% and 69.0% respectively). AUC and the kappa coefficient were fair for the MST compared against GLIM (AUC 0.63, kappa 0.26). When compared with ESPEN, the MST demonstrated fair sensitivity and specificity (60.7% and 58.0%), and poor AUC and kappa coefficient (0.59 and 0.09 respectively).

When using the FFMI instead of SMI within the GLIM criteria, similar results were found with a prevalence of 46.2%. The agreement between the three criteria remained the same (7.2%). The same proportion of patients were identified as malnourished by both the GLIM and ESPEN criteria (n = 51). Sensitivity (60.5%), specificity (69.5%), AUC (0.65) and the kappa coefficient (0.30) were all classified as fair when comparing the GLIM criteria using the FFMI with the MST.

Table 4
Accuracy of the MST against diagnostic tools (GLIM and ESPEN) (N = 444).

	FP	FN	Sensitivity	Specificity	PPV	NPV	AUC	kappa
GLIM	66	100	56.7	69.0	66.5	59.5	0.63	0.26
ESPEN	163	22	60.7	58.0	17.2	91.0	0.59	0.09

GLIM; Global Leadership Initiative on Malnutrition, ESPEN; The European Society for.
Clinical Nutrition and Metabolism, MST; Malnutrition Screening Tool,FP; false-positives.
FN; false-negatives, kappa; kappa coefficient, PPV; positive predictive value, NPV; negative predictive value, AUC; Area Under the Curve.

4. Discussion

The GLIM criteria showed a prevalence of malnutrition in half of the geriatric rehabilitation patients, most of whom were moderately malnourished. Only a small proportion of patients were identified as being malnourished or at risk of malnutrition according to all (GLIM, ESPEN and MST) criteria. Furthermore, the accuracy of the MST was low compared to the GLIM and ESPEN criteria.

4.1. Prevalence of malnutrition

A recent study provided GLIM-defined malnutrition prevalence in older acute hospitalised patients at 25.7% (13% stage 1/moderate and 12.6% stage 2/severe malnutrition) [45] which is comparable to our overall prevalence if the MST malnutrition risk was applied prior to applying the GLIM criteria. When the GLIM criteria were applied without the MST malnutrition risk, our study's malnutrition prevalence was within previously reported ranges for malnutrition in geriatric rehabilitation populations [5–8]. In addition, studies where the Patient-Generated Subjective Global Assessment (PG-SGA) or Subjective Global Assessment (SGA) methods are used showed similar prevalence to GLIM [46]. The similar etiologic and phenotypic assessments in GLIM, PG-SGA and SGA may explain similar prevalence rates; all three incorporate body composition, GIT symptoms, inflammation and disease for the aetiology of malnutrition, in addition to weight loss and dietary intake.

Table 3
Characteristics of malnourished and not malnourished patient phenotypes at admission (N = 444).

	GLIM (n = 81)	GLIM&ESPEN (n = 19)	GLIM&MST (n = 99)	GLIM&ESPEN&MST (n = 32)	ESPEN (n = 3)	ESPEN&MST (n = 2)	MST (n = 64)	Not Malnourished (n = 144)
Age, years	84.2 [79.0–88.0]	87.7 [80.0–89.7]	84.8 [78.9–87.7]	85.0 [79.5–88.4]	80.5 [77.0–81.8]	83.9 [82.2–85.6]	84.8 [79.0–88.9]	81.6 [76.0–86.2]
Sex, female, n (%)	26 (32.1)	5 (26.3)	37 (37.4)	18 (56.3)	1 (33.3)	1 (50.0)	55 (85.9)	109 (75.7)
HADS anxiety, score	3 [1–8]	2.5 [2–8.5]	4.5 [2–9]	2.5 [1–5]	–	–	6 [3–12]	6 [2–10]
HADS depression, score	5 [1–9]	3.5 [2.5–8]	6 [3–11]	5.5 [2–8]	–	–	7 [3–11]	6 [2–10]
BMI, kg/m^2	25.3 [22.0–29.1]	19.9 [18.0–22.2]	24.6 [22.0–28.6]	19.5 [17.3–22.0]	18.3 [17.38–21.3]	18.4 [14.6–22.1]	27.4 [24.2–30.6]	30.4 [26.5–35.1]
HGS (kg) females	14 [9.5–18]	16 [10–20.5]	14 [10–18]	12 [10–17.5]	–	–	14 [12–17]	14 [10–19]
males	20.5 [16–27]	17 [10–21]	19 [16–28]	16 [12–22]	20.5 [18–23]	–	20 [20–30]	22 [20–30]
IADL, score	1 [0–1]	1 [0–1.5]	1 [0–1]	1 [0–1.5]	1 [0.5–1]	0 [0-0]	1 [0–1]	1 [0–2]
ADL, score	2 [1–3]	1 [1–2]	1 [1–2]	2 [0–3]	1 [0.5–3]	3.5 [3–4]	2 [1–3]	2 [1–3]
CIRS, score	12 [9–15]	10 [8.5–12]	12 [9–15]	11.5 [10–15]	6 [5–9]	7.5 [6–9]	10 [7–13.5]	10 [7–14]

Data presented as median [IQR] unless otherwise indicated. GLIM: Global Leadership Initiative on Malnutrition; ESPEN: European Society for Clinical Nutrition and Metabolism; MST: Malnutrition Screening Tool; HADS: Hospital Anxiety and Depression Scale; BMI: Body mass index; HGS: Handgrip Strength; IADL: Instrumental Activities of Daily Living; ADL: Activities of Daily Living; CIRS: Cumulative Illness Rating Scale; IQR: interquartile range.

The prevalence of malnutrition according to the ESPEN definition was lower compared to GLIM criteria in geriatric rehabilitation patients. The disparity between the diagnostic tools is seen in ESPEN's requirement to link weight loss with either low BMI or FFMI malnutrition diagnosis, whereas GLIM criteria requires only one of these. The use of SMI instead of FFMI in the GLIM criteria did not account for the disparity between the GLIM and ESPEN prevalence rates as similar results were found if the FFMI had been used within the GLIM criteria. GLIM criteria's addition of etiologic criteria further explains the higher prevalence compared to ESPEN. In recent studies the prevalence of malnutrition according to the ESPEN definition was 7.3% in healthy community-dwelling older women [47], 6.73% in geriatric diabetic patients [48] and 7% in geriatric outpatients [49] which is comparable with the prevalence in our population when MST is applied prior to the ESPEN definition.

There are a limited number of prevalence studies utilising MST specifically within the geriatric rehabilitation setting, however, prevalence of 35% malnutrition risk has been found in older outpatients [50] and 56% prevalence amongst hip fracture inpatients [51]. The Mini Nutritional Assessment (MNA) is more commonly used in geriatric rehabilitation populations with a prevalence of malnutrition risk found to be 28–63% [52].

4.2. Agreement and clinical phenotypes

The group of patients diagnosed according to all three criteria (GLIM, ESPEN & MST malnutrition risk) had the lowest handgrip strength. Low HGS is associated with poorer health outcomes in older people [53] and low BMI <22 kg/m^2 has been found to increase mortality risk by 52% and risk of fracture by 38% in older patients [54].

Most of the patients who were malnourished according to the ESPEN definition were also captured by the GLIM criteria, which is to be expected due to shared phenotypic criteria. The higher proportion of malnourished males within the GLIM group and GLIM&ESPEN group can be explained by the comparatively higher muscle mass cut-offs for skeletal muscle mass index. While consensus on cut-off points for muscle mass and diagnosis of sarcopenia are still being determined in the literature [55,56], the SMI cut-offs used in our study are appropriate for BIA measures in older people.

4.3. Malnutrition screening

Both GLIM and ESPEN consensus statements recommend the prior use of a malnutrition screening tool. When the screening was applied, a large proportion of patients within our study were not detected by MST who would otherwise be diagnosed as malnourished by GLIM and/or ESPEN criteria. The MST demonstrated a sufficient level of validity as a screening tool when compared with GLIM, however, sensitivity and specificity do not reach the levels of ≥70% recommended as adequate in the literature [42,57]. A study investigating malnutrition according to the ESPEN definition in a geriatric outpatient population assessed prevalence both with initial screening (6%) and without initial screening (7% when applied to the whole population) [49]. The same study diagnosed 8% malnutrition prevalence within young healthy adults without prior screening to demonstrate the possibility of false positives [49]. In our study, there is a larger difference between prevalence rates based on whether screening is used in conjunction with GLIM or ESPEN. It has been recently suggested the sensitivity of GLIM's criteria may lead to false positives and therefore function as a screening tool itself [58] however this is yet to be determined by validation studies.

4.4. Limitations

A limitation of the current study is the use of MST criteria to indicate reduced food intake and weight loss for both GLIM and ESPEN phenotypic assessments, including the severity of malnutrition in the GLIM definition. Accurate self-reported information on dietary intake is difficult to obtain at hospital admission in this population, however, the MST gave some indication of poor appetite and thus suboptimal intake. Similarly, weight loss history captured by the MST tool relies on self-reported and often unquantifiable data so it is possible that weight loss has been underestimated.

4.5. Strengths

The current study is the first large prevalence study focusing on malnutrition according to the new GLIM criteria within a geriatric rehabilitation setting, a group that is known to be at high risk of malnutrition. Our study is based on a CGA, which provides methodology via validated and standardised assessments appropriate to older patients and performed by a multidisciplinary team. CGA is known to contribute towards improving outcomes for independence and mortality in older patients [59] and the findings of this research will add to the body of literature on malnutrition prevalence in geriatric rehabilitation patients.

5. Conclusion

This study is one of the first to demonstrate the use of the new GLIM criteria for the diagnosis of malnutrition, indicating that one in two geriatric rehabilitation patients are malnourished and therefore at increased risk for poor health outcomes. As there was a small agreement in malnutrition prevalence and risk between GLIM, ESPEN and the MST there is a need for further studies to validate GLIM as the global diagnostic criteria for malnutrition.

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Statement of authorship

ABC, EMR and ABM were responsible for the conceptualization; data curation; formal analysis; investigation; methodology; visualization. ABC wrote the original manuscript and EMR, WKL and ABM were responsible for supervision, review and editing of the manuscript.

Conflict of interest

All authors declare no conflicts of interest and no financial disclosures that could inappropriately influence their work.

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